Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 3 (2015) 5631 – 5638

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Ergonomics design of healthcare NFC-based system

Danco Davcev[a]*, Goran Jakimovski[b]

[a]*Faculty of Computer Science and Engineering, Skopje, Macedonia*
[b]*Faculty of Electrical Engineering and Information Technology, Skopje, Macedonia*

Abstract

Implementing a software system that modifies the work habit of employees can often lead to disapproval of the system and potentially make their jobs worse. This is often the case when implementing new healthcare system in medical centers, where the system is intended to help medical personnel and patients, but due to bad implementation or miscommunication leads to bad healthcare system. In this paper we are using ergonomic factors in order to improve the design of the proposed NFC-based healthcare system. Using these factors, modifications can be made to the system in order to provide better user experience and better healthcare.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of AHFE Conference

Keywords:Cloud; Ergonomics; healthcare; Medical; NFC

1. Introduction

As Near Field Communication (NFC) becomes standard equipment in personal mobile devices, it can be used to provide fast information for authentication, emergency medical information and access to medical history of patients. This means that patients equipped with NFC devices can securely access the medical mobile cloud with simple proximity of their NFC, [1]. Furthermore, patients can schedule appointments as described in [2], while medical personnel can access their patient's entire medical history and update it with current diagnosis using their NFC. As new technology is often denied by users, we are using Quality of Experience (QoE) metrics[3] to evaluate the patients' and medical personnel's experience. In this paper, we are testing the system on users and using their experience as a performance evaluation of the system, [3]. As NFC cards are equipped with internal memory,

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
*E-mail address:*dancodavcev@gmail.com

2351-9789 © 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.770

patients can have critical information stored on their NFC card for fast access in critical situations. This information can vary and can be configurable. Information such as blood type and allergies can be stored as critical fast access data. Also, information such as critical CAT scans, insulin injections, diabetes or disproof of medicine due to belief, [4], can be beneficial to emergency medical personnel. The paper is organized as follows. In Section 2, the architecture of the proposed system is presented, along with points of access and usage of the NFC card for authentication and authorization. Section 3 presents two applications of the system, where users (patients and medical personnel alike) interact using the healthcare cloud system to perform scans and application of the NFC fast-access stored information. Section 4, using the applications presented in Section 3, presents our ergonomics analysis based on QoE metrics. Section 4 also presents test case scenarios and results of the users of the system beyond the applications presented in Section 3, where using QoE metrics, patients and medical personnel alike can express their experience of using the system. Section 5 concludes the paper based on results from Section 4.

2. Architecture of proposed system

The NFC-based mobile medical cloud architecture is a fully integrated cloud system for tracking, analyzing, storing and providing on-demand medical information to patients and medical personnel. Using the NFC all-in-one medical card, users authenticate to the system using NFC ID. Users can be patients, medical personnel or external entities that require information from the system. Each user, using their NFC-enabled mobile device, can require access to the system and according to his permission, execute a request *(upload or download medical information, perform tests, scans and online analysis)*. On the other hand, the system communicates with medical equipmentvia internet or intranet. Figure 1 illustrates the concept of the system.

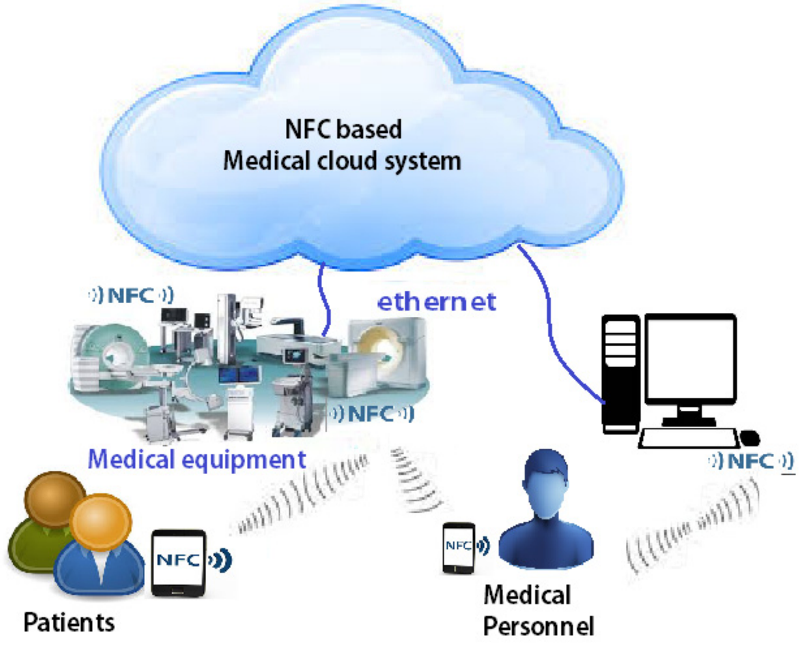

Figure 1 Medical mobile cloud system architecture

The users of the system are the patients, doctors, nurses, specialists, paramedics and external entities that were grant monitored access to certain medical records, [4]. The system is patient-centric, which means that each action taken, relates to patient's medical history or healthcare. Each patient is equipped with all-in-one medical card and is identified in the system with it. Patients can view their medical history, insert symptoms that they had during the day or schedule an appointment at their doctor or some specialist. Before taking an action, the patient has to identify himself in the system using the NFC card. This means that the patient, using a device (laptop, smart phone, tablet, desktop PC…), can remotely access the system by inserting his NFC card and sending his/hers NFC ID to the system. Furthermore, when the patient has (scheduled or unscheduled) appointment, uses his NFC card to authenticate at the doctor’s office and automatically the system creates a session for that patient. The system creates an appointment report for that patient, identified with his NFC, and is granted access to the doctor to insert symptoms and eventually finish the appointment with diagnosis, prescriptions and/or specialist appointment. When at the specialist’s office, the patient again creates appointment session (using the NFC) where scans, tests and results are written. All medical equipment has NFC authenticators which are used to identify the patient and to update his current open session with scans and test results.

Medical personnel, such as doctors, nurses and specialist are also equipped with NFC cards. Doctors and specialists are using their NFC cards before appointments to authenticate in the system and authorize the appointment giving the system information which medical personnel did the appointment. Using NFC as authentication and authorization method in the Mobile Medical Cloud system is important part of the system’s security and reliability since medical data is vital, crucial and protected by the Health Insurance Portability and Accountability Act of 1996, [5]. If patient’s diagnostic is written by mistake to another patient, it could lead to providing patients with inappropriate medical care leading to health degrading and possible death, [6]. Furthermore, unauthorized access to patient’s medical files directly violates doctor-patient confidentiality and can cause serious health risk if those files were inaccurately changed. To avoid this, NFC card protects patient’s data and maintains appropriate access to authorized personnel. This would mean that if a patient does a CAT scan, first the patient is authenticated by its NFC card, then the medical personnel authenticates by using its NFC card and the Medical cloud system authorizes the CAT scan.
In Figure 2, the use case scenarios of system usage are presented.

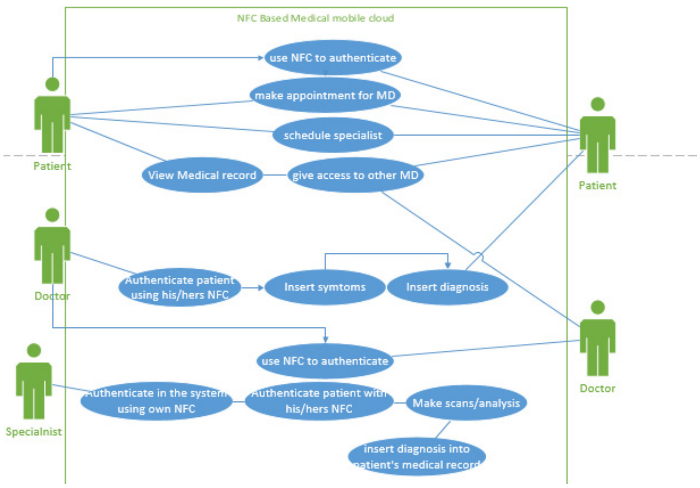

Figure 2 Use case diagram of the system identifying the users of the system

The patient further uses his NFC-enabled mobile device for fast access to critical data. The NFC card has information about blood type, allergies and treatments to avoid or to commence recent medication prescriptions. Due to limited amount of memory the NFC card has, it can hold up to 10 or 15 latest or crucial diagnostics of the patient. The NFC card can be used in critical situations, such as traffic accidents, disasters, and car or plane crash. In case of a natural disaster, people often find themselves in a no service situations, which means that there is no internet connectivity and phone signal is low. This means that Paramedics cannot access the system or it takes too much time to retrieve information. In such cases, paramedics can obtain crucial information about a patient with a simple touch of their NFC devices. Even though, the entire medical history can be accessed via the Medical cloud, critical situations can also occur in rural areas with low or no internet connectivity. Thus, storing crucial data on the NFC card can be very beneficial in providing on time and accurate medical care. Crucial medical data stored on the

NFC card can be configurable and is divided as fixed or variable information. Information such as blood type, allergies, insulin injections or invalidity can be considered fixed and non-changeable information about a patient, whereas information such as last antibiotic injection, migraine or latest crucial bone fractures can be configurable.

3. Application of the system

In this section we will describe two applications of the system presented in Section 2.

3.1. Procedure for MRI scans of patients

In this part of the paper we are describing, in more detail, the procedure for MRI scans of patients and how the NFC is facilitating the process. This procedure is then analyzed in section 4 using the ergonomics QoE parameters of the patients and specialists using this procedure. As described in section 2, each appointment at the specialist's office is started with the patient's NFC authentication in the system and starting a specialist's session. Then, the specialist approves the session by using his NFC card. Each scan that is further made using the MRI scanner in the specialist's office is written to the patient's session record, signed by the specialist and kept in the patient's medical record. The sequence diagram of the procedure is presented in figure 3.

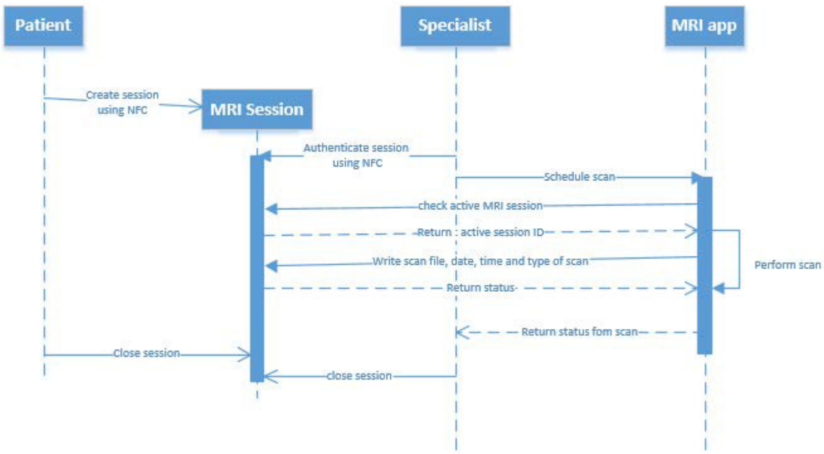

Figure 3 Sequence diagram of the MRI scan procedure

From figure 3 we can see that the entire process is done automatically with little to no interaction from the patient or the specialist. This way, the human error in medical diagnosis is set to minimum and all appointments and doctor-patient sessions can be finished in less time than before. The specialist's office has desktop PC with NFC device that communicates via internet with the Medical Cloud system for authentication and session control. The MRI application is enhanced with a small shell script that checks to see if there is an active MRI session in progress in the system. If there is, each scan image is saved in the Medical Cloud and shown in the MRI application. If there isn't any session active, the MRI application displays an error message box, saying that the images were not sent to the Medical Cloud system.

3.2. Procedure for manipulation of NFC medical emergency information

Online systems that are accessed remotely can become useless if there is no internet connection on the intended device. This means that even the most advanced high-technology systems could become inoperable in case of no connectivity. In our Medical Mobile Cloud, inoperability of the system in the doctor's office may not pose a threat to patient's healthcare, but there are cases in which the system is used outside the safety zone of the medical institutions. If a patient is found in a car/plane accident or natural disaster such as flood or earthquake, the only medical personnel available are the paramedics. Inoperability of the Medical Cloud system on the field can be due to low or no connectivity ofthe medical mobile devices. If paramedics cannot access the system, they cannot obtain critical information about a patient, such as blood type, allergies or recent medical prescriptions. If a patient is bleeding and needs immediate blood infusion, paramedics have to check the blood type and pressure and then treat the patient. This operation takes time and could further deteriorate his health and could lead to bad healthcare. Furthermore, information such as allergies to certain drugs or recent prescriptions that could contradict other medications cannot be obtained on the place of the accident. That is why we are using the NFC card's internal memory to store offline critical fast access information that would be more than beneficial in case of emergency.

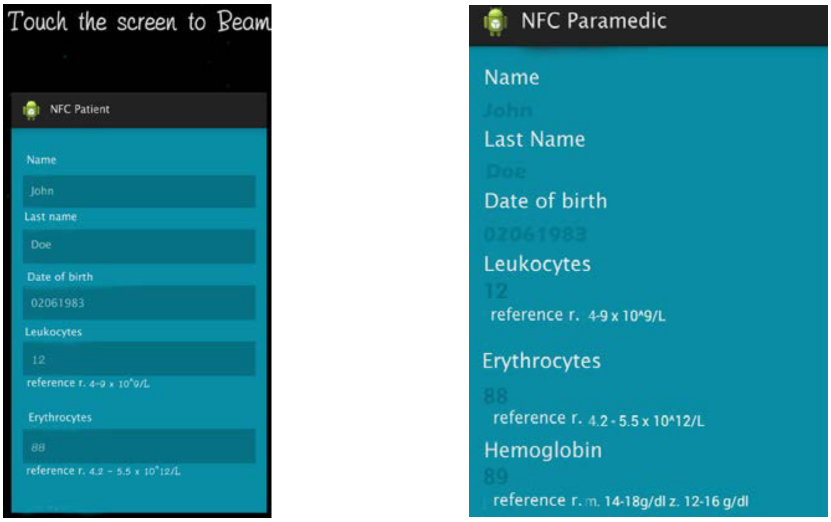

Figure 4 Screenshots of the procedure for Beaming offline medical data between patient and paramedic using NFC

The NFC card has limited storage capacity (up to 64KB for tagging), but it can use the NFC equipped device to store and load emergency medical data. Our offline emergency medical system uses around 1MB of memory, where about 100 KB is used for information such as blood type, allergies, information from medical treatments that might be important such as low blood pressure, low or high blood sugar or diabetes, and some additional bytes for doctor's notes that he/she considers might be beneficial in emergency situations. The remaining memory is used to store the essential image(s) from medical scans (CAT, MRI, …) that the doctor considers crucial.

When the patient is first included in the medical cloud system, critical and non-changing information is transferred to the NFC equipped device and from that point on, the NFC card can be used for providing offline medical emergency information. Further, each time the patient goes to a doctor's appointment, if there is some new crucial emergency information that the doctor finds it beneficial for offline storing, it uses the medical cloud system to update information for offline usage.

The screenshots of the procedure for Beaming offline medical data between patient and paramedic using NFC are shown in Figure 4. The screenshot on the left shows the patient's NFC device and the information stored, whereas the screenshot on the right shows the paramedic's NFC device. By touching the patient's screen to beam, the offline information is transferred from the patient's to the paramedic's NFC device, and the paramedic can read (as an example) the Name, Surname, blood type, hemoglobin, erythrocytes and other blood related parameters. The android application has options for the paramedic to see images of scans (if any) and statistics (which parameter is above or below normal values) of the patient using his offline information.

4. Ergonomics analysis based on QoE metrics

We have made some ergonomic analysis on our proposed system using the QoE metrics which is based on patents' and medical personnel surveys. Our analysis is oriented towards ergonomics design and how this analysis is going to change the proposed system. Our main objective of the medical ergonomics analysis was to evaluate whether the NFC-based medical system has improved patient-doctor interaction. Since the system is medical-based, it means that patients with different age would have to use the system. It is expected that elderly patients would have more difficulty in using the system, so a group of 20 patients and medical personnel, ranging from 20 to 70 years of age were chosen to conduct the ergonomic analysis and measure the QoE parameters. Children and teenagers were not included in the survey as their medical experience is guided by their parents or legal guardians. The QoE metrics used in the survey include analysis of the usage of medical personnel and patients. For patients, the analysis includes factors such as system accessibility, better communication with medical doctors, less time spent in the waiting rooms and overall practical usage of the system.

QoE factors of the medical personnel are divided in two parts. The first part of the survey for medical personnel examines how well the doctor can use the system and how the system can help the doctor to be more efficient in his/her work. The second part of the survey focuses on the necessity of the automatic analysis of medical information and prediction of diagnosis. This survey is used to evaluate the opinion of the medical personnel about using suggested pre-diagnosis of the system. The parameters and results are given below.

From Table 1 we can see that the system gives acceptable results in acquiring and input of medical data. From Table 2 and Table 3 we conclude that majority of the patients and doctors were satisfied from using the system and gained better medical experience due to it.

Table 1 displays the results of the ergonomics QoE analysis of the system itself. In this table we have the overall functionality of the system, uptime and accessibility of users to the system. This table makes no distinction between users, but rather analyses how the medical system is globally accessed and used. Table 2 shows the patient-centric QoE parameters and Table 3 shows the medical personnel parameters.

Table 1 gives the summed up, short answers from the following questions (question group no. 2 with 12 testers):

1. How much time does it take to make an appointment? How does the process go?
2. How much time does it take to get information about the patients?
3. Do any problems occur? And if they do, how would you fix that?
4. Are you comfortable with the present system? What is his speed? Do you have any obstacles? And if you do, how would you fix them?
5. Is the present system better than the old one? This means working with less paperwork and using the Internet.
6. How much time does it take to sum up the patient's whole medical history?

Table 1 Ergonomic analysis of the entire system

Type of a medical person	QN1	QN 2	QN 3	QN 4	QN 5	QN 6
Nurse number 1	Depends on the Internet	We need to wait	No	No	Yes	A little
Nurse number 2	1 min.	1-5 min.	Yes, fixing for 5-10 min.	There are	Yes	Around 2 min.
Nurse number 3	Fast	Right at the moment	Yes	There are, but they are fixed shortly	Yes	5 min.
Nurse number 4	2 min.	Right at the moment	Yes	There aren't	Yes	5 min.
Doctor number 1	Depends where is free	Right at the moment	Sometimes	There are	Yes	Immediately
Doctor number 2	Depends if there are terms, if not	/	Yes, with a quicker database it'd	/	Yes	Little

	they wait		be fixed			
Doctor number 3	Depends where, around 2 min	Shortly	There aren't	Few in the beginning, now they are solved	Of course	Immediately, it takes only a few minutes
Doctor number 4	Around 15 min.	Immediately	There are, most are with the stability of the Internet	Too dependent on the Internet	Partially	Few hours
Doctor number 5	10 sec. – 10 min.	Immediately	System overload	Sometimes, system overloads	Yes	Immediately
Dentist number 1	1 min.	Yes	Immediately	It is comfortable	Yes	Around 5 min.
Dentist number 2	With more doctors it would be faster	Immediately	There aren't	There are	Yes	Immediately
Psychiatrist	It takes about 5 min	Fast, immediately	There aren't	There aren't	Yes	Around 15 min.

Table 1 presents the results of 12 of the 20 testers of the system and displays the ergonomic analysis of the entire system and its functionalities. The parameters tested include system response time, necessity and how much the NFC-based cloud medical system improves the standard paper medical system. Figure 5 displays the histogram of the analysis done in Table 1.

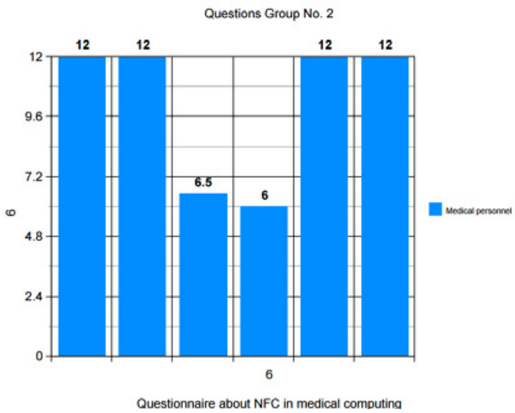

Figure 5 Diagram of the ergonomics analysis of the entire system

Table 2: Overall analysis (1..10)

How many patients	Percentage (%)
have adequate mobile devices?	73%
have NFC?	41%
were satisfied from using the system?	79%
experienced better medical care?	61%
would use the system on daily basis ?	52%

Table 2 presents the ergonomics parameters tested from the patients' usage of the system and if the NFC-based medical cloud system improves or deteriorates patients' medical experience. Parameters include system accessibility, ease of use and overall patient satisfaction and opinion. Table 3 gives the doctors perception of the system usage.

Table 3: Overall analysis (1..10)

How many doctors	Percentage (%)
have more work done?	75%
experienced better patient interaction?	67%
have worse diagnostics due to the system?	24%
have difficulty using the system?	38%
think the system puts more workload?	85%

The ergonomics analysis is used for system evaluation from the user's perspective. The technical specification and implementation of the system is not always accepted by the users. The results presented in tables 1, 2 and 3 mainly prove the system design and implementation as an improvement over the standard paper-based medical system. Main problem of the NFC-based medical cloud system, according to the ergonomics analysis, is the additional equipment (NFC card) that each user should obtain and use it with any medical related event. Patients usually forgot or don't have the NFC card, which could be considered as an obstacle in system usage. More than 80% of users (patients and doctors alike) are satisfied by the system and claim that the system has improved access to patients' medical history and improved medical checkups by automatically updating information and access to the entire patient's medical records. Patients experienced difficulties in the process of scheduling appointments and the system resulted in many empty appointments (patient scheduled with no show).

5. Conclusion

In this paper, we presented the basic architecture of our NFC based healthcare system as well as our first results from ergonomics analysis based on QoE metrics. As can be seen from the analysis, our system was well accepted by the users. More than 80% of users (patients and doctors alike) are satisfied by the system and claim that the system has improved access to patients' medical history and improved medical checkups by automatically updating information and access to the entire patient's medical records. It is especially important that elderly patients have accepted the system based on these new ICT technologies with no difficulty.

In our future work, we plan to apply the QoE metrics to larger groups of users and to improve the design of the system according to the user's perception and satisfaction.

6. References

[1]Sethia, D. , Gupta, D., Mittal, T. , Arora, U. , Saran, H., NFC Based Secure Mobile Healthcare System, 2014 Sixth International Conference on Communication Systems and Networks (COMSNETS), 2014 , pp 1 - 6

[2] Yeo S.M., SankaranarayananS., Near Field Communication based Patient Appointment, 2013 International Conference on Cloud & Ubiquitous Computing & Emerging Technologies (CUBE), 2013, pp 98 - 103

[3] Sarlan A., Ahmad R., Ahmad W. F. W., Dominic P.D.D., Users' Behavioral Intention to Use Clinic Information System: A Survey, 2012 International Conference on Computer & Information Science (ICCIS) Volume:1, 2012, pp 37 – 43

[4] Kang, K., Wang, Q., Hur J., Park K., Sha L., Medical-Grade Quality of Service for Real-Time Mobile Healthcare, Computer: Computing in healthcare Feb. 2015, pp 41 – 49

[5]Li, J., Ensuring Privacy in a Personal Health Record System,Computer: Computing in healthcare, Feb. 2015, pp 24 – 31

[6] Madisetti, V., Bahga, A., Healthcare Data Integration and Informatics in the Cloud, Computer: Computing in healthcare Feb. 2015, pp 50 – 57